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Analog Temperature Records from a Linearized Thermistor Network

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To overcome the inherent disadvantage of nonlinear output, a system was developed consisting of a thermistor network and operational amplifiers to produce a linear analog temperature record, either on strip charts or magnetic tape.

Keywords: Temperature measurements, temperature sensors.

Thermistors are used extensively for temperature measurements, primarily because they are highly sensitive and recording equipment is quite inexpensive for routine applications. One feature that offsets these advantages is their inherent nonlinear output. This characteristic is a more noticeable disadvantage when analog records are desired over a temperature range of several tens of degrees (such as meteorological records of air temperature). The system described here uses a thermistor network and operational amplifiers to produce a linear analog record of temperature, either on strip charts or magnetic tape.

A network containing two thermistors and two precision resistors closely approximates the ideal linear sensor. Harruff (1967) predicts a deviation from linearity of less than ± 0.2 percent of the sensor range for the circuit of figure 1. Such networks are commercially available. The one used in this system is manufactured by Yellow Springs Instrument Company.[2] This sensor has a range of -30° to +50°C, with a specified linearity deviation of +0.16°C when input voltage is 3.0 volts or less.

For the circuit in figure 1, the transfer function provided by the manufacturer for this particular sensor is

$$E_{out} = (+0.0067966\ E_i)T + 0.34893\ E_i$$

where T is temperature in degrees C. This relation holds for load resistances greater than 1 megohm at E_o.

Figure 2 shows the circuit designed as an interface between this sensor and an analog tape or strip chart

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[2]*Trade names and company names are used for the benefit of the reader, and do not imply endorsement or preferential treatment by the U.S. Department of Agriculture.*

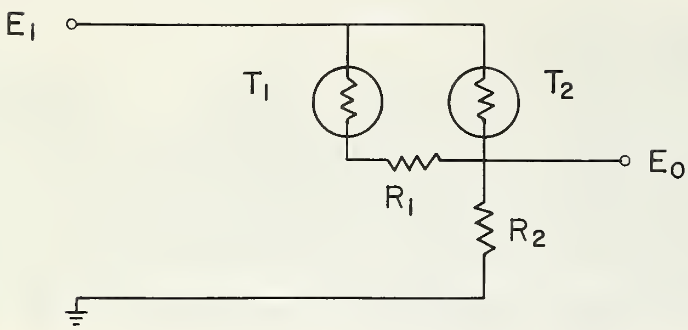

Figure 1.—Dual thermistor network.

recorder. Primary design considerations were: (a) high input impedance to the sensor, and (b) convenient outputs for both tape and strip chart recorders. Zener diode D1 and amplifier A1 provide a reference voltage across divider R5 through R9. The wiper voltage at R6 is buffered by A2, to provide the sensor excitation voltage, E_i. Amplifier A3 follows the voltage of the wiper on R6, to yield a zero offset, E_z. Sensor output, E_o, is buffered by A4, with an input impedance of 10 megohms. Differential amplifier A5 subtracts the zero offset voltage from the sensor output. This signal is amplified by 10 at A6 to provide a signal for magnetic tape recording. The voltage to current converter, A7, drives a strip chart galvonometer. This design was obtained by applying operational amplifier techniques described in Tobey et al. (1971).

The probe in figure 3 was designed to protect the dual-thermistor bead and house the sensor components with a minimum increase in response time. Figure 4 presents response curves for two laboratory

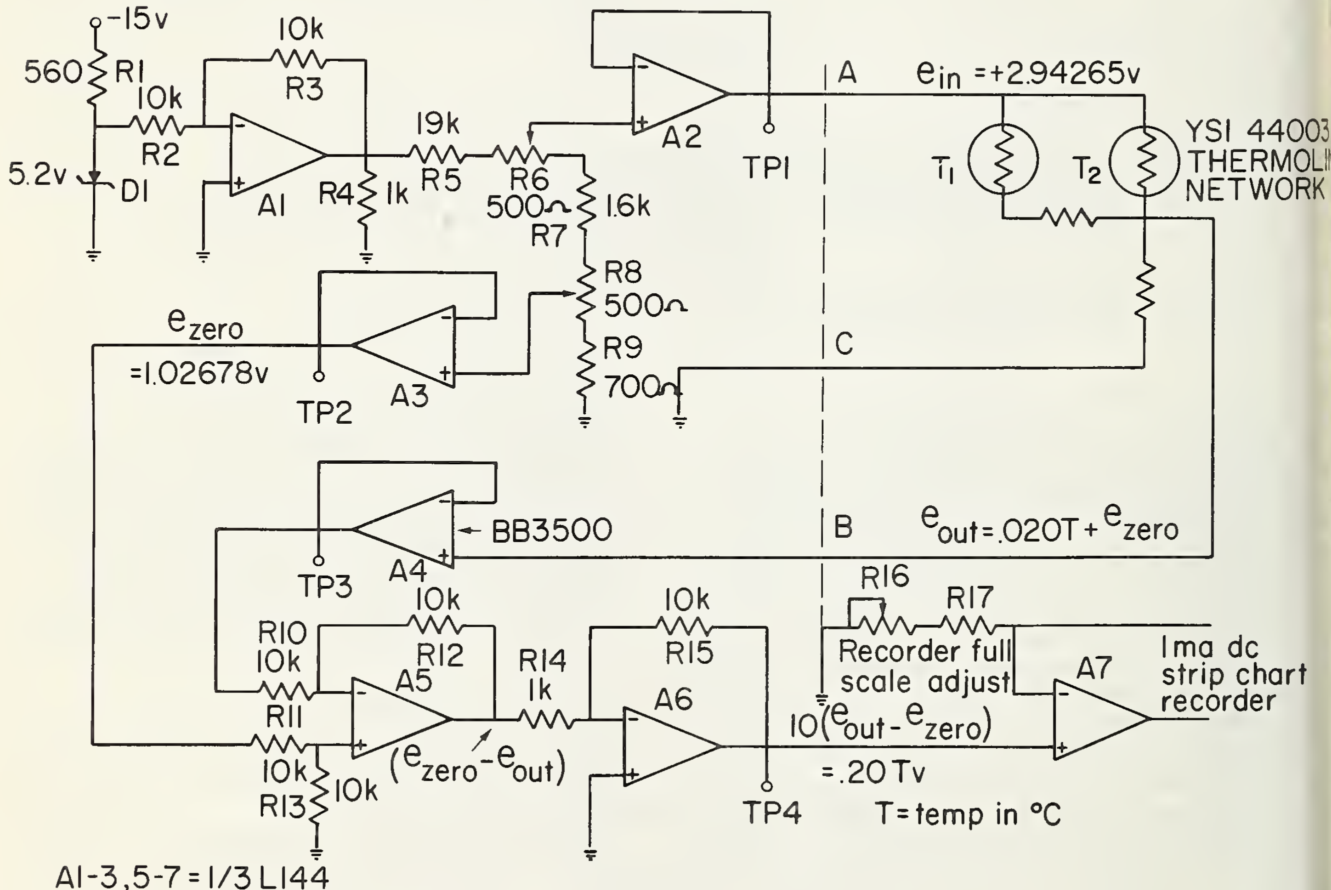

Figure 2.—Interface circuit for the linear temperature recorder.

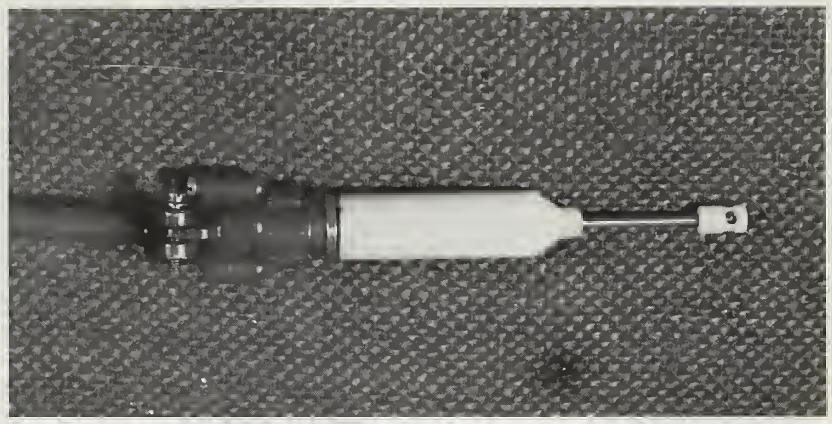

Figure 3.—

The sensor probe

protects the

dual-thermistor bead.

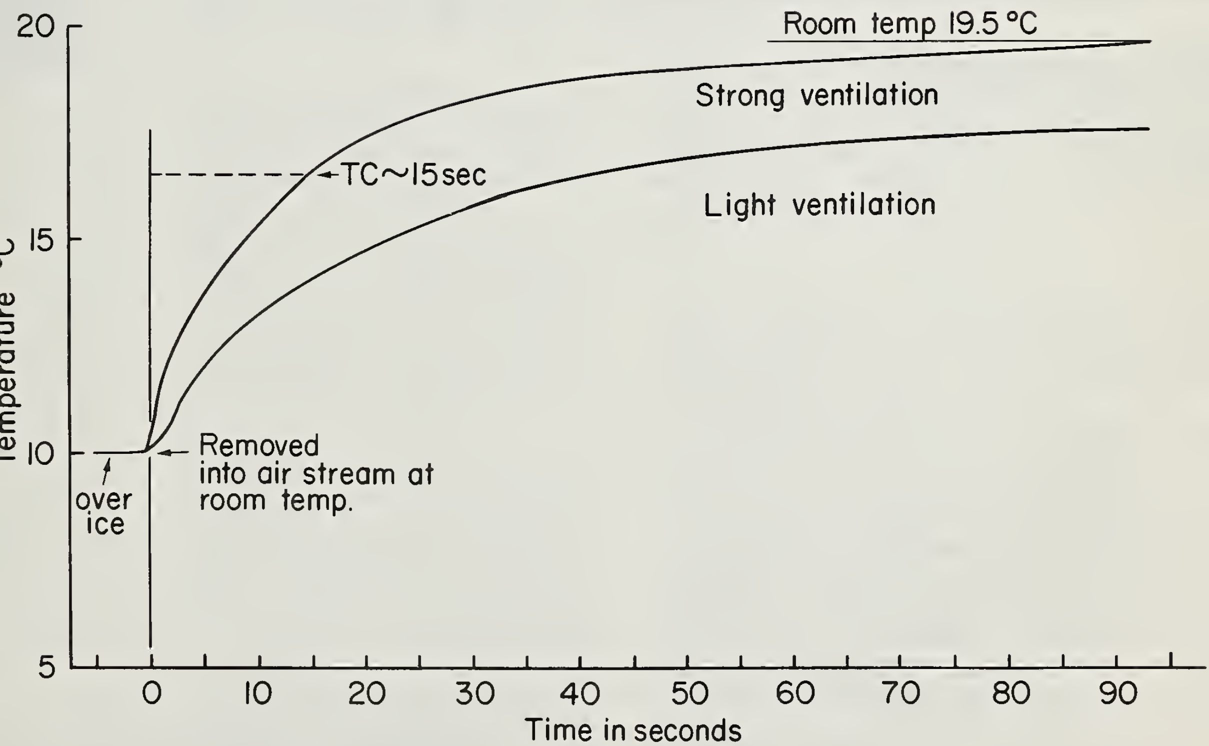

Figure 4.—Response time of the sensor.

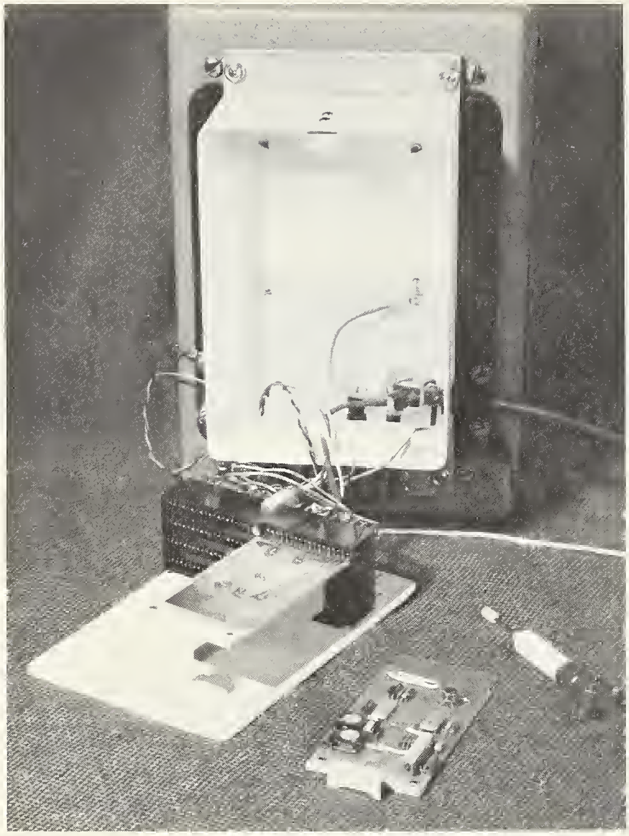

Figure 5.—Printed circuit and housing mounted on a strip chart recorder.

situations. Figure 5 shows the printed circuit board that implements figure 2. This board and one containing a modular $\pm$15-volt power supply are installed in a case attached to the back of the strip chart recorder.

The strip chart recorder output is adjusted by first setting the recorder's mechanical adjustment to indicate 0°C when the probe is at thermal equilibrium in an ice bath. The probe is then placed in an environment of known temperature near the value of the extreme to be recorded, and R16 adjusted to obtain the proper indication.

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